Some warm and some hot in MOND phenomenology

Moti Milgrom (Weizmann)

The basic premises of the MOND paradigm

Modified dynamics at low accelerations as an alternative to Newtonian Dynamic (with DM)

- The appearance of a new acceleration constant in dynamics, a_0
- Standard limit : $a_0 \to 0$
- MOND limit, $a_0 \to \infty$: $\quad a_0, \; G \to a_0 G$ for pure gravity

Various theories: modify the Poisson equation; modify Newton's second law; modify GR

Independent
Kepler-like laws of galactic dynamics

- Asymptotic constancy of orbital velocity: $V(r) \to V_\infty$
- The mass-velocity relation (baryonic TF relation): $V_\infty^4 = MGa_0$
- $\sigma^4 \sim MGa_0$ relation ("isothermal" spheres, deep MOND virial relation)
- Discrepancy appears always at $V^2/R = a_0$
- Isothermal spheres have surface densities $\bar{\Sigma} \leq a_0/G$
- The thin-lens approximation is not valid
- Disc galaxies have a disc AND a spherical "DM" components

- Added stability of discs with $\bar{\Sigma} \leq a_0/G$

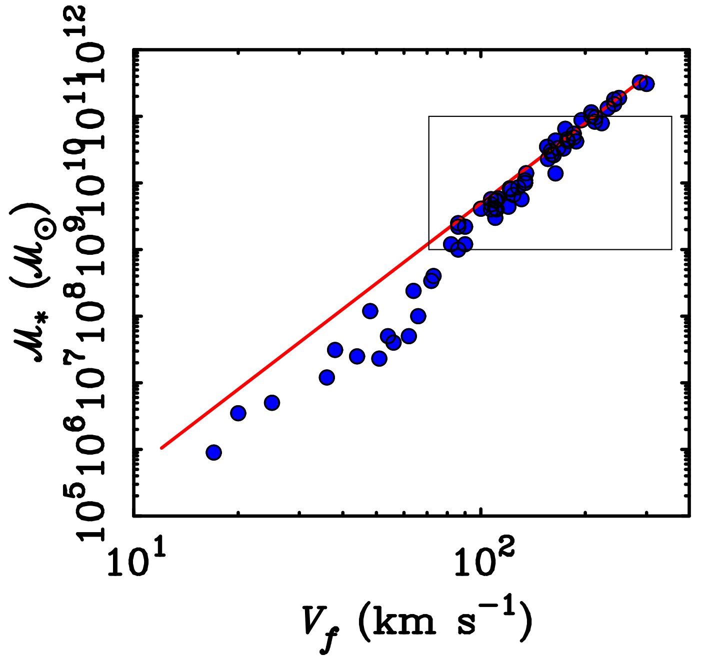
- The external-field effect

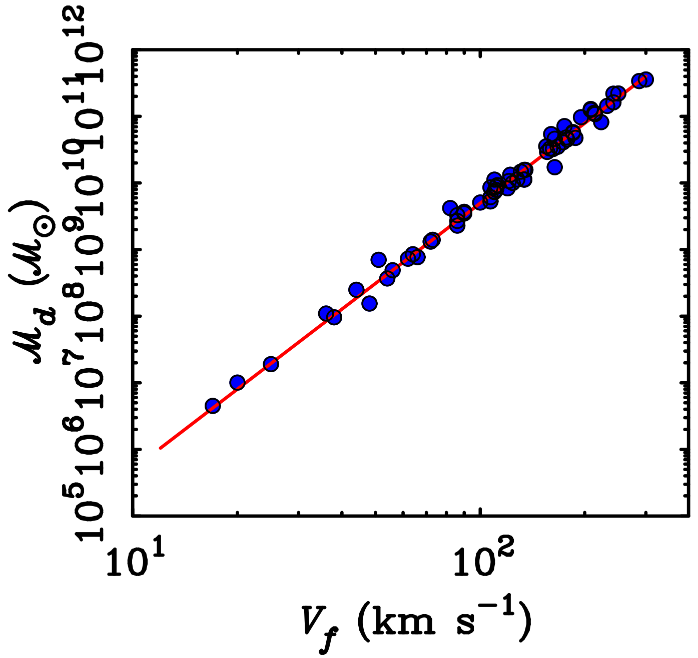
- Special role of the transition radius: $r_t \equiv (MG/a_0)^{1/2}$

- Excess acceleration always $\lesssim a_0$

- Negative density of "dark matter" in some locations.

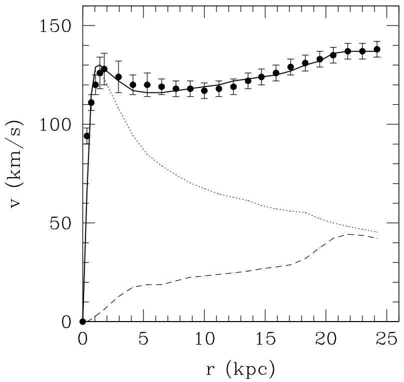
The mass-velocity (baryonic Tully-Fisher) relation

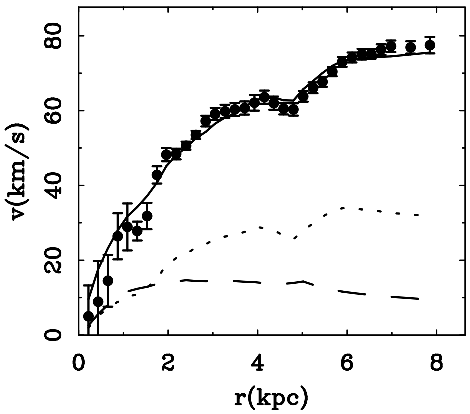


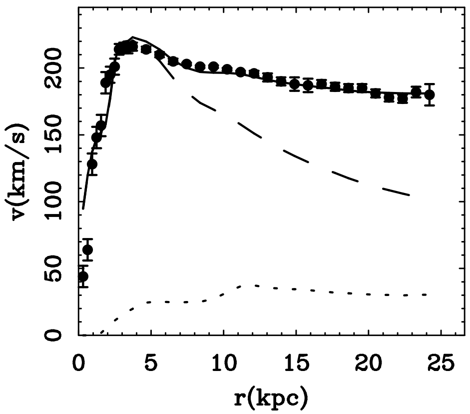


from McGaugh 2006

Rotation Curves of Disc Galaxies



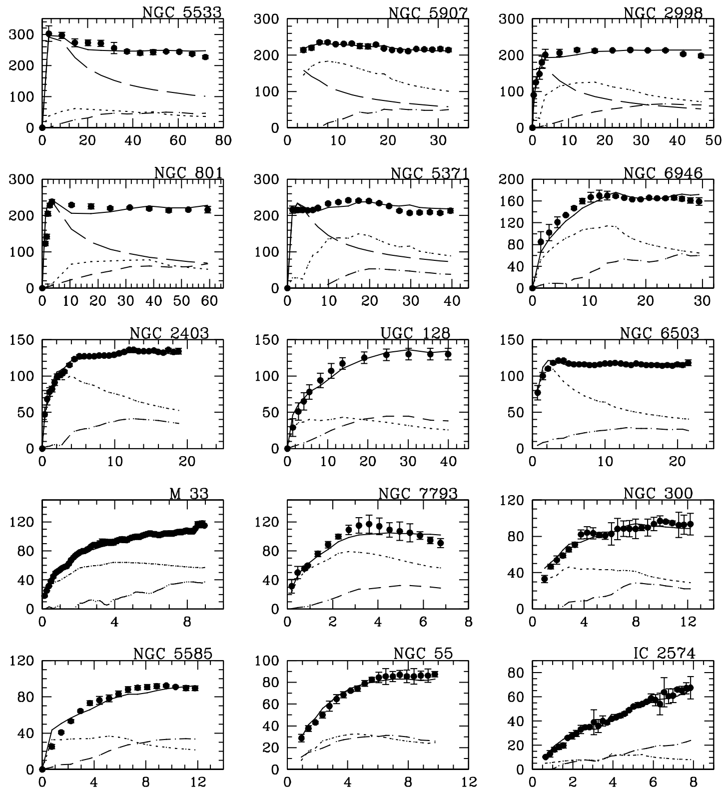


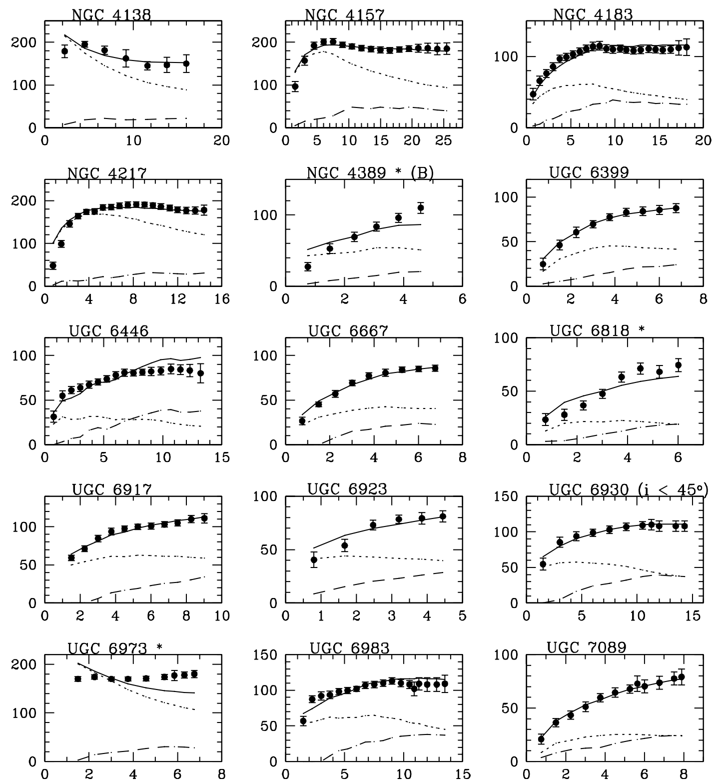


Sanders (2005)　　　　Sanders and McGaugh (2002)

Rather robust to change in theory

For modified inertia $a\mu(a/a_0) = \phi'(R)$, with $a = V^2/R$ and $\mu(x)$ universal





Sanders and McGaugh 2002

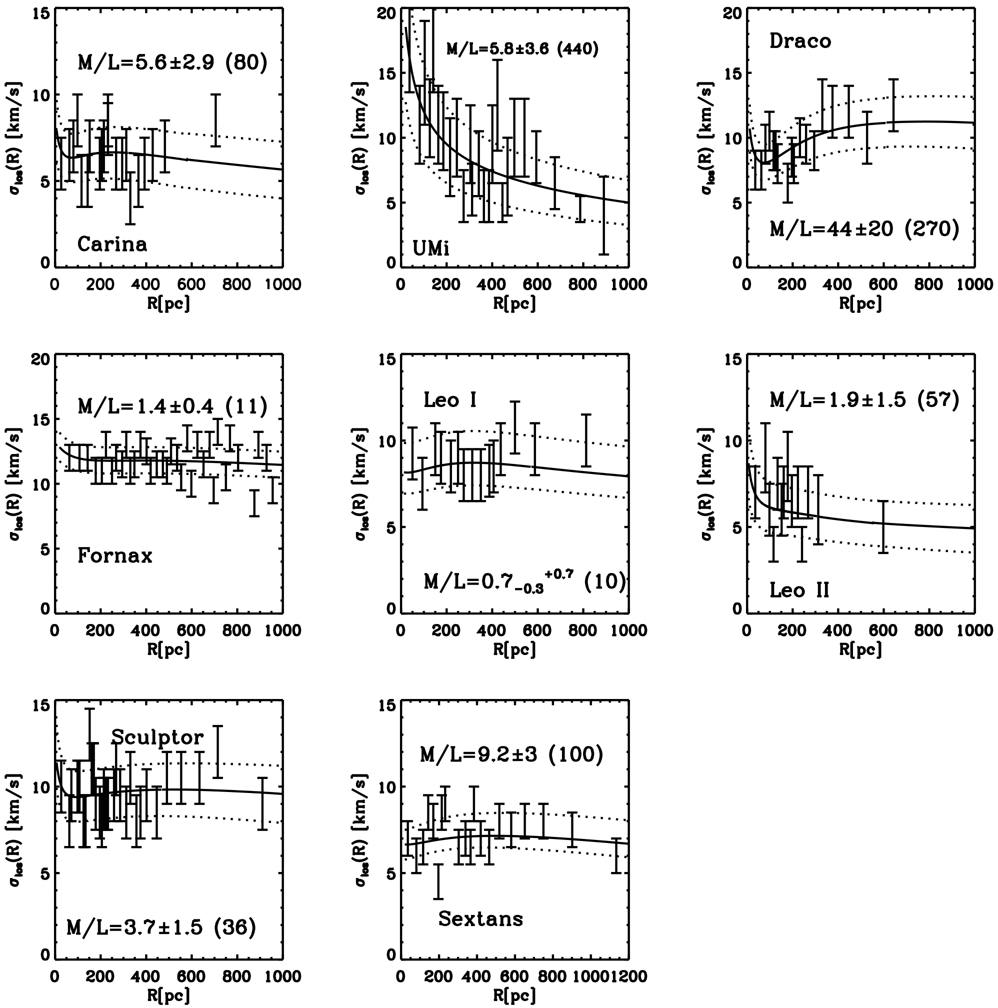
$a_0 = ?$

a_0 can be derived in several independent ways:

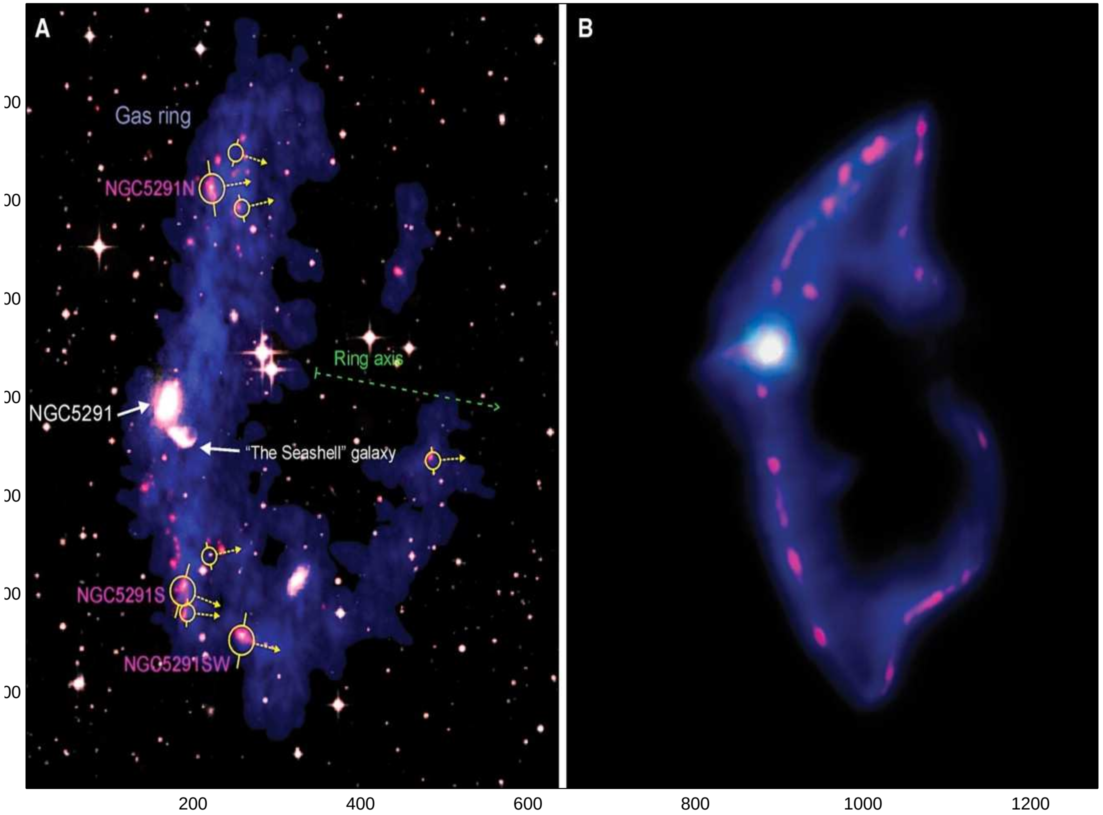
$$a_0 \approx 1.2 \times 10^{-8} \text{ cm s}^{-2}$$

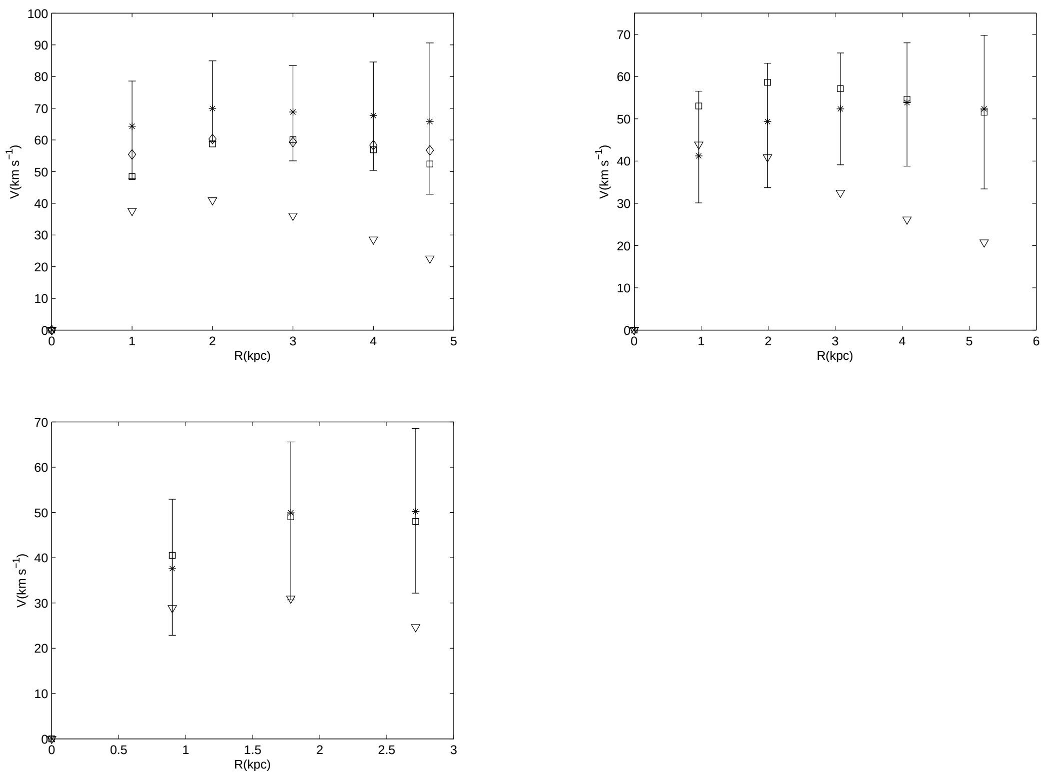
- $2\pi a_0 \approx cH_0$
- $2\pi a_0 \approx c(\Lambda/3)^{1/2}$

Dwarf spheroidals (Angus 2008)



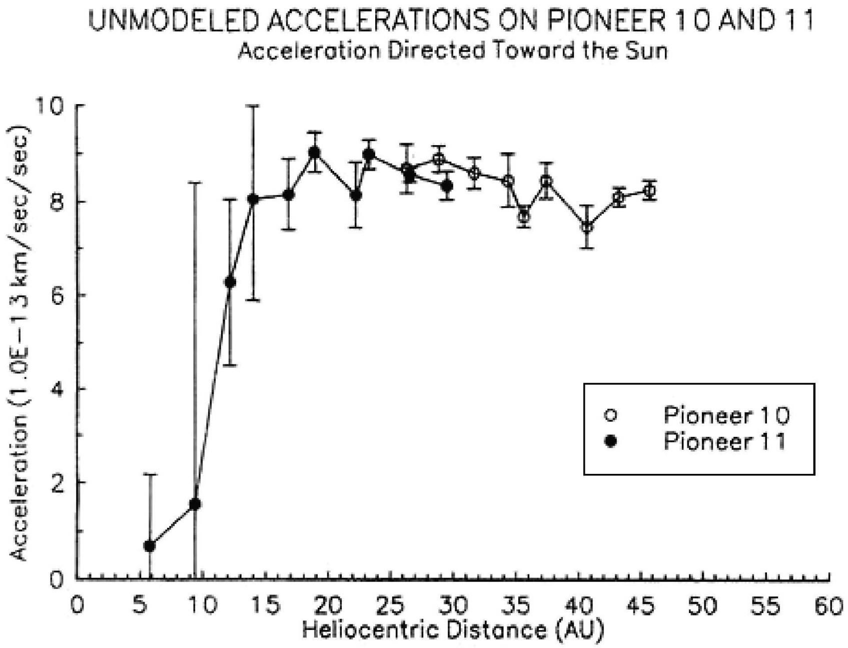
Debris dwarf galaxies

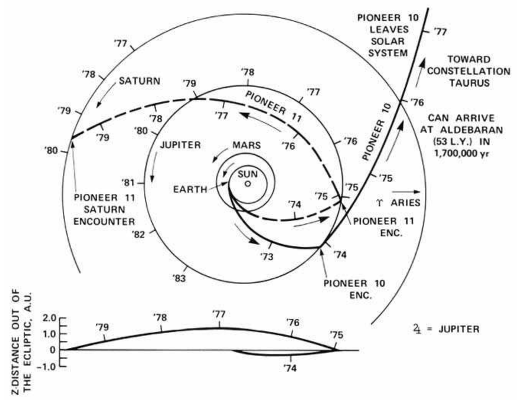




Data and Newtonian analysis from Bourneau et al (2007) MOND analysis: Milgrom (2007)

Solar System: the Pioneer Anomaly



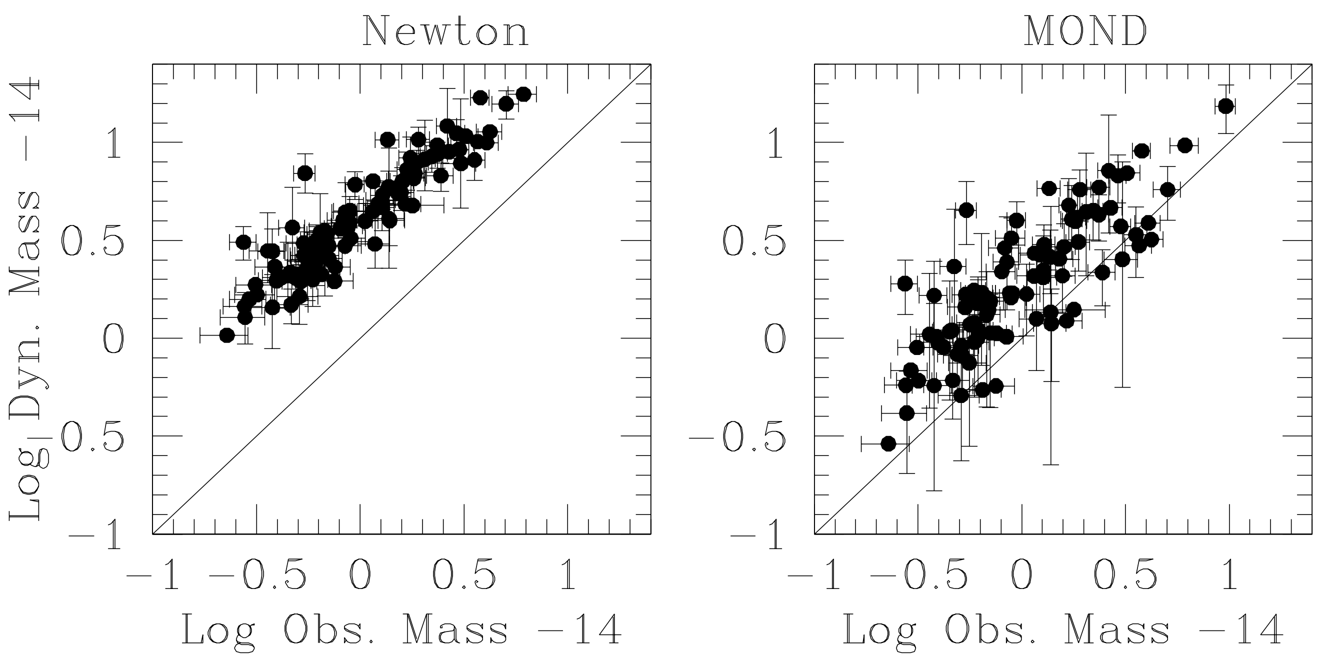


From Anderson et al. 2002

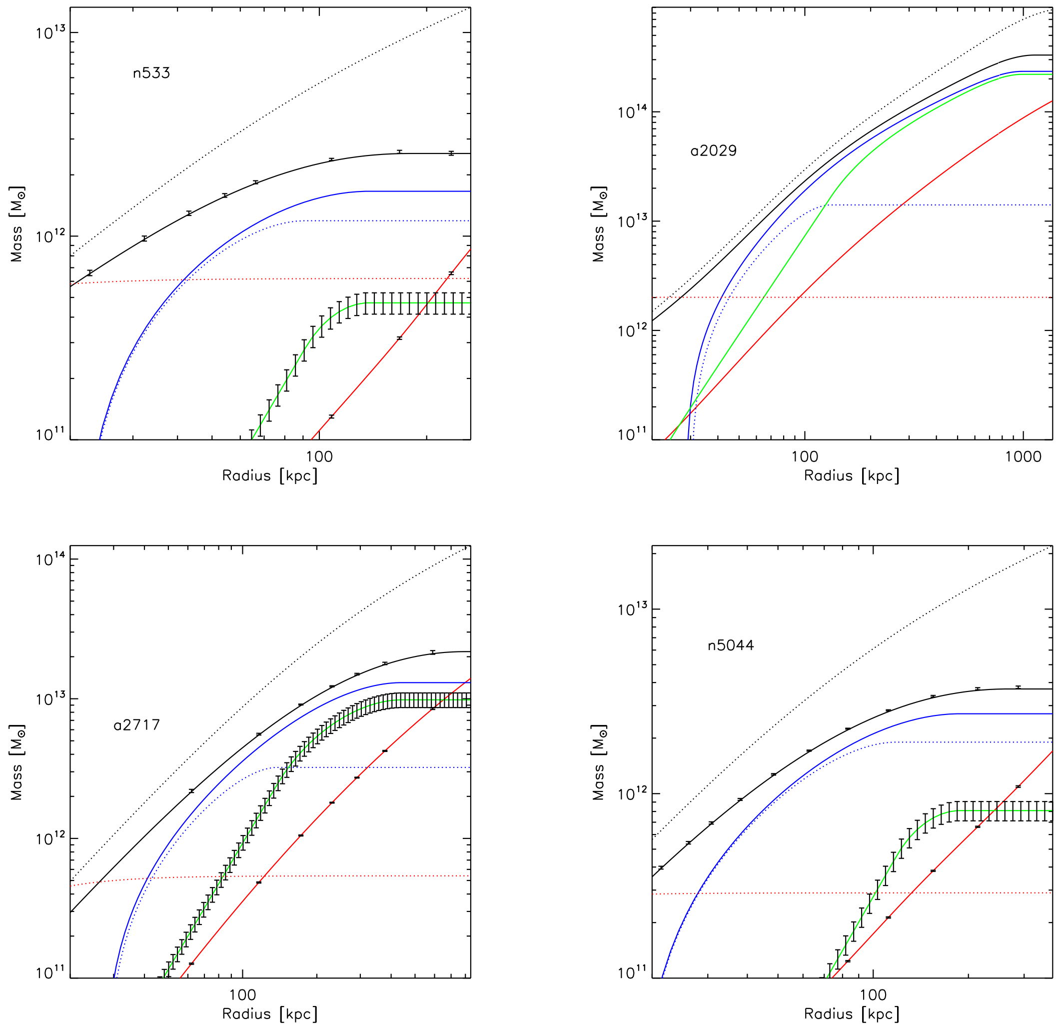
MOND and galaxy clusters

- Early 1990s: MOND does not explain the discrepancy in cluster cores
- Measured acceleration within a few 100 kpc are $> a_0$
- Modify MOND to account for this?
- Most reasonable solution: some yet undetected baryons (Milgrom 2008)
  - ▷ $M(CBDM) \sim M(gas)$
  - ▷ Only a small contribution to nucleosynthesis value
  - ▷ May be helpful in preventing cooling in the cores

BDM in clusters according to MOND

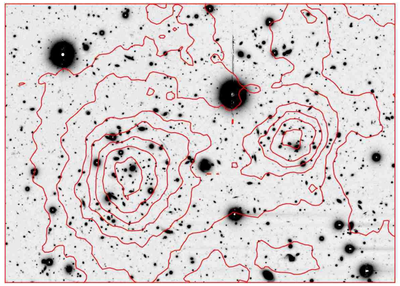


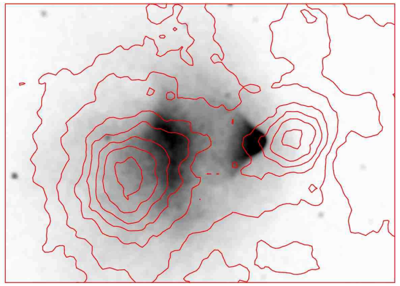
Sanders 1999



From Angus et al. 2008

The bullet cluster





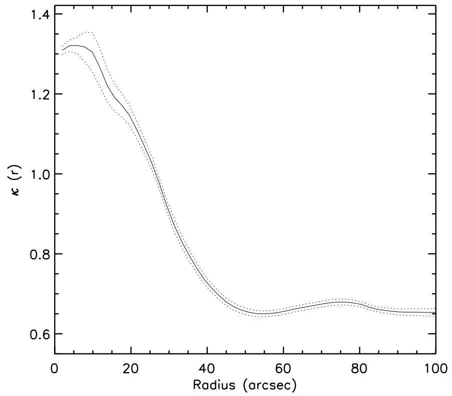
Clowe et al. 2006

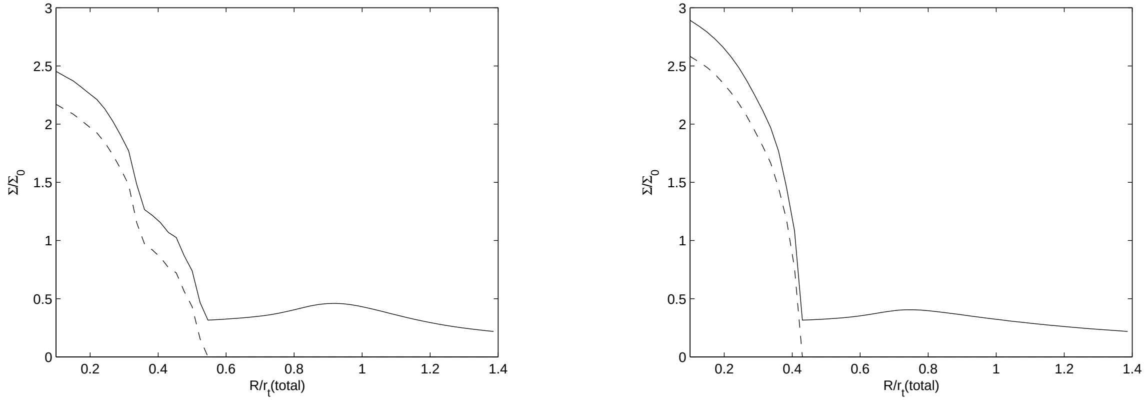
Results expected from what we know on isolated clusters (Angus et al. 2006)

BDM is largely non-dissipational

The high-relative-velocity problem

The "ring" cluster (Cl 0024+17)





Jee et al. (2007)

Milgrom & Sanders (2008)

MOND defines the transition radius $r_t \equiv (MG/a_0)^{1/2}$ (analog to $r_G = MG/c^2$)